# Field Workshop on Subsurface Fractures in Glacial Till and Their Environmental Implications: An Educational Experience for Professionals and Decision-makers[1]

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ABSTRACT. **This paper documents the history of the Ohio Fracture Flow Working Group and describes their conceptualization, planning, coordination, and implementation of a unique outdoor field workshop on joints and fractures in glacial till held in London, OH, on 28 August 1997. The one-day event was coordinated and staffed by geologists, soil scientists, well drillers, and engineers. More than 175 people were in attendance, representing local, state and federal agencies, colleges and universities, and the private consulting sector. The field day included a morning lecture series of short plenary presentations and four afternoon field demonstration stations. The field stations included geophysics (downhole gammalogs, surface resistivity arrays), hydraulic conductivity testing (slug tests), two drilling rigs (an angle auger rig and a rotosonic rig), and a series of drilling cores that were described by a glacial geologist, two soil scientists, and a geotechnical engineer, demonstrating the different approaches, terminologies, and classifications that each discipline uses. The final field station was a large three-tiered pit approximately 10m × 25m and 3.7m deep that was used to demonstrate soil profiles and how they were formed, their relationship to the underlying glacial till deposits and the associated polygonal fracture patterns, and the difference in hydraulic conductivity between areas of fractures and areas of no fractures. Participant evaluations were very favorable, and plans are being made for future educational work on fractures.**

**OHIO J SCI 100 (3/4):94–99, 2000**

## INTRODUCTION

### An Educational Need: Understanding of Fractures

For the most part, water percolating down from the ground surface in moderately fine- and fine-grained glacial materials to underlying ground water moves through fractures and unconformities, not by means of flow between the grains as is common in a sand and gravel setting. Because the rates of drainage can be more rapid within these fractures, reaching as much as three orders of magnitude faster than laboratory hydraulic conductivity measurements would indicate (McKay and Fredericia 1995), there is little time for the water to interact with the materials it is passing through. While this is not necessarily a problem when considering water movement, it is a critical issue when considering the kinds of contaminants that can move with that water. Whether the contaminants originate from local point sources or regional non-point sources, these materials can be carried down into the underlying ground water, where they become part of the source water for private drinking water wells and public water supplies. The role of fractures in this process, while vitally important, is often not well understood by environmental professionals and decision-makers. In Ohio, with its proliferation of fracture-prone soils (Tornes and others 2000), there is a need for educational programs that address this issue.

International research is building, documenting the critical importance of fracture flow in surface to ground water transport settings. However, this information is generally being published in a variety of technical journals, often overseas, and is not readily available to the local and state decision makers and professionals who need the information for their daily activities. In addition, a core group of individuals who represent state and federal agencies, universities and private sector organizations have been undertaking significant research and/or making significant observations in Ohio that also need to be shared with a much broader audience.

Perhaps most importantly, the individuals who would be the most affected by the research into fracture flow are not necessarily the same group who are making the discoveries. This information has far reaching impacts for planning and development decisions being made by county health departments and local planning and/or zoning boards, but these groups do not interact with research soil scientists and geologists on a regular basis. It would be very unlikely that they would read hydrogeological publications from Europe and Canada where most of the advanced research is being published.

### Environmental Education Field Workshops

Science educators are becoming increasingly aware of the need to teach scientific concepts while making explicit the context, purpose, and practical implications of that science (Helms 1998). Using a natural setting as the classroom for environmental workshops allows the learners to directly interact with the topic being discussed, and observe and/or participate in some of the specific skills and field techniques being taught. Field-based education increases the authenticity of the learning, facilitates a stronger connection between ideas and applications, and helps the learners remember the experience better (Helms 1998; Lee and Caffarella 1994).

Some recent examples of field laboratory education

[1]Manuscript received 21 July 1999 and in revised form 11 January 2000 (#99-24).

in the literature include an outdoor learning habitat for elementary school children in Boulder, CO (Bishop 1998), a wetlands restoration field project for ninth graders in the San Francisco Bay area (Helms 1998), an outdoor land lab at a Navajo high school in Arizona (Foster 1997), and a small-scale sustainable agriculture demonstration farm project for college biology and environmental science courses in upstate New York (Feldman 1999). These emphasize practical hands-on learning in a field laboratory setting. There are many more examples from the 1970s and 1980s, including the establishment of land labs in Illinois (Swanson and Tucker 1978), Maryland (Talbert 1983), Ontario (Eagles and Richardson 1992), and Sierra Leone (Swanson and Tucker 1978). In Ohio, a popular land lab program was called "Habitats for Learning." Assistance for developing these labs in Ohio has been provided by local Soil and Water Conservation Districts and the Ohio Environmental Education Fund.

A recent survey of educational literature showed that references relating to environmental education, including descriptions of land labs, were much more prevalent in the 1970s than in the 1980s and 1990s (Wilson and Smith 1996), suggesting that environmental education had become less of a priority in schools and teacher education programs. A study by Simmons (1998) cited the barriers and benefits, as perceived by educators, to using outdoor educational programs. The benefits and barriers included enthusiasm mixed with safety concerns for the students and lack of confidence in their own preparation for teaching in natural areas.

### History of the Ohio Fracture Flow Working Group

A Putnam County study of a failing landfill in fractured lake clay created a significant amount of discussion between soil scientists and glacial geomorphologists in Ohio. In March 1993, a Working Group was convened by researchers at The Ohio State University and the Columbus-based environmental consulting firm, Bennett & Williams. There were approximately 15 scientists at the first meeting, representing six organizations and agencies. That May, at the Annual Meeting of The Ohio Academy of Science, the Lake Plains Working Group was formed under the umbrella of the Academy to act as a coordination point and educational outreach program for fracture flow research in Ohio.

The Working Group continued to grow and currently is comprised of an interdisciplinary team of researchers with expertise in the fields of geology, soil science, agricultural engineering, environmental science and engineering, city and regional planning, public health, plant science, law, and earth science education. To better reflect their wider membership and expanded mission, the Lake Plains Working Group changed its name to the Ohio Fracture Flow Working Group. In April 1994, at the annual meeting of The Ohio Academy, a formal one-day Symposium was held. Almost 100 people were in attendance, representing multiple disciplines as diverse as hydrogeology and public health. Each succeeding year, fracture flow presentations were made at the annual meeting of The Ohio Academy of Science. But academic presentations alone could not convey the whole story, and in 1996, discussions about planning a field day began. The objective of the remainder of this paper is to document the conceptualization, planning, coordination, implementation, and participant evaluation of a unique outdoor field workshop on joints and fractures in glacial till held in London, OH, on 28 August 1997.

## MATERIALS AND METHODS

### Planning and Preparation

The Ohio Fracture Flow Working Group chose an outdoor field workshop format as it seemed to be the best approach for reaching the largest number of people in a visual, hands-on setting. The Working Group could have chosen the more traditional route of trying to introduce the information through college courses but this takes far longer to reach the consensus level in the professions. Very little information is covered on the subject even in the newer hydrogeology textbooks (Domenico and Schwartz 1997). New textbooks would have to be written and adopted before the next generation of soil scientists, hydrogeologists and engineers would recognize the importance of fracture flow. Even then, sanitarians and planners would not be taking those courses and thus would probably not be exposed to the research. While the Ohio researchers could publish in national professional journals, these papers would miss a critical target audience in Ohio. In addition, no professional journal paper can ever hope to create the impact that a hands-on workshop produces. Not only can everyone see for themselves how important the issue is, but they can learn from each other as they discuss the day's events with other professionals from other disciplines, creating a synergism that can lead to sound decision making at their own local level.

Recognizing these issues, the Working Group was determined to hold a field day. Financial considerations of hiring backhoes and drilling equipment delayed implementation of this vision. In the late winter of 1997, the geotechnical drilling firm, Bowser-Morner of Dayton, OH, agreed to donate the use of two drilling rigs for a field day demonstration. McFarland & Sons Inc., an excavation contractor from Circleville, OH, offered the time to construct a major pit, charging only their costs to rent a large, oversized backhoe. The Working Group quickly mobilized, organizing a full one-day field event to be held 28 August 1997, at The Ohio State University Molly Caren Agricultural Center in Madison County. Planning for the event took six months. On-site preparation took four days with as many as 15 people working at a time. Approximately 30 earth scientists, engineers and students were required to coordinate and staff the field event.

### Description of Workshop

The field day included a series of introductory lectures and four outdoor field stations (Weatherington-Rice and Christy 1999). The day began with a series of short plenary presentations on glacial geology, hydrogeology and soils to orient the diverse group of learners. After that, those in attendance were separated into four groups, each with an assigned field leader who specialized in a particular area. Several other selected individuals who were qualified to discuss other aspects of the day's activities were placed in each group. This arrangement encouraged ongoing discussions as the group moved from station to station.

The first field station included a geophysical demonstration by the Indiana Geological Survey of downhole gamma logging (in a PVC cased well) and surface resistivity arrays. This site also included a demonstration of how to conduct and interpret slug tests in a shallow monitoring well. Participants were cautioned about the over-reliance on values derived from slug test data. The site was staffed by geologists, hydrogeologists and agricultural engineers. The second station included two types of drilling rigs: a hollow stem auger rig set up to drill angled borings and a rotosonic rig. This site was staffed by geologists and drillers. The third site consisted of a series of drilling cores that were described by a glacial geologist/hydrogeologist, two soil scientists and a geotechnical engineer, demonstrating the different approaches that each discipline would take when reviewing a core and the different terminologies and classifications that each discipline uses.

The final site was a large, three-tiered pit approximately 10 m × 25 m and 3.7 m deep (Fig. 1) which was staffed by glacial geologists and soil scientists. This site was used to demonstrate: 1) the soil profiles and how they were formed, 2) the relationship of the underlying glacial till deposits with associated polygonal fracture patterns, and 3) the difference in hydraulic conductivity between areas of fractures and areas of no fractures. Records for the two hydraulic conductivity tests performed over several days indicated an average hydraulic conductivity of 0.006 cm/hr within the unfractured polygons and 0.026 cm/hr at the intersection of five fractures. These measured values are considerably faster than the typical $1 \times 10^{-6}$ cm/sec (0.0036 cm/hr) to $1 \times 10^{-8}$ cm/sec (0.000036 cm/hr) reported for glacial tills from geotechnical laboratory samples (Prudic 1986; LaFleur 1979). This large difference between the field demonstration data and laboratory analysis results indicates that laboratory conditions do not fully account for "true" hydraulic conductivity in fractured environments, further emphasizing the importance of field testing and first-hand knowledge of field conditions. This reiterates the essential nature of providing field training for all environmental professionals and decision-makers.

## Evaluation Techniques

Evaluation forms were distributed at the beginning of the day and participants were encouraged to make notes on the forms as they moved from station to station. Those in attendance were asked to leave the forms at the end of the day but the forms were also designed to be self-mailers if someone wanted to think about their responses before returning them. Questionnaires were

FIGURE 1. Field station demonstration pit with participants at the field workshop on joints and fractures in tills, 28 August 1997.

divided into two sections, one evaluating the introductory lectures section and one on the field sites. Learners were asked specific questions and could respond using a five-point numerical rating: excellent (5), good (4), average (3), below average (2), and poor (1). There was also a section for comments.

## RESULTS

More than 175 people participated in the one-day event. An additional 50 people were turned away for lack of space. Those in attendance represented the fields of geology, hydrogeology, engineering, soil science, and public health. The audience came from local, state, and federal agencies, colleges and universities, and the private consulting sector. The level of technical understanding on the subjects presented (including glacial geology, soils, and fracture formation) ranged from those who were completely unfamiliar with the topic to the leading experts in the field in Ohio. A concerted attempt was made to create a meaningful learning experience for all who attended, regardless of their level of expertise. Continuing education credits (CEUs) were granted to the registered sanitarians who attended.

While only 33 forms were returned, there were numerous informal responses that were made over the next several months to the organizers. The field day is still a topic of discussion when workshop attendees gather at professional meetings three years later. Table 1 summarizes the evaluation results. Not every respondent replied to each question. For most participants, the large pit was their favorite aspect of the workshop, garnering the highest average rating of 4.78 out of 5. The following were representative of the remarks submitted on the comments section of the evaluation forms:

TABLE 1

*Evaluation results of field workshop on subsurface fractures.*

| | Range* | Average |
|---|---|---|
| Introductory Lectures: | | |
| 1. Quality of speakers' delivery | 5 – 3 | 4.00 |
| 2. Quality of speakers visual illustrations and/or handouts | 5 – 2 | 3.94 |
| 3. Organization of lecture materials | 5 – 3 | 4.19 |
| 4. Receptiveness of speakers to questions and comments | 5 – 3 | 4.61 |
| 5. Extent to which speakers stimulated your interest | 5 – 3 | 3.97 |
| 6. Amount of knowledge gained from lectures | 5 – 2 | 3.78 |
| 7. Overall quality of all speakers | 5 – 3 | 4.15 |
| 8. Overall quality of the workshop | 5 – 3 | 4.30 |
| Field sites: | | |
| 1. Azimuthal resistivity | 5 – 2 | 4.13 |
| 2. Gamma logging | 5 – 2 | 4.16 |
| 3. Slug test | 5 – 3 | 3.90 |
| 4. Drilling | 5 – 2 | 3.73 |
| 5. Large pit | 5 – 3 | 4.78 |
| 6. Hydraulic conductivity testing | 5 – 3 | 4.30 |
| 7. Core description | 5 – 2 | 3.87 |

*Note: excellent = 5, good = 4, average = 3, below average = 2, and poor = 1. Results are based on 33 surveys returned out of a possible 175.

"Excellent design and organization relative to fascinating problem of pollution through till fractures. Also excellent design of pit."

"The pit was wonderful!"

"The pit was great."

"I learned a lot from looking at a big hole."

"Field demonstrations and pit exposures helpful in visualizing till structures."

Strongest points were "pit, conductivity comparison."

Some constructive criticisms and suggestions for improvement were also proffered:

"Good overview of a broad subject area in one day. Hard to compress this much into one day–could expand to 2 days and have more hands-on by participants."

"No real discussion possible of issues."

"Great topic, good material, too many people."

Weakest points were "lectures, handouts."

Most of the comments were positive and indicated that the workshop had indeed met a felt need:

"Till is often over-generalized as relatively impermeable. This workshop highlights that till can have permeable zones, and presented techniques for characterizing these zones."

"Got to see in action a lot of things you just read about."

The strongest point was the "variety of presentations and demonstrations."

The strongest point was the "multi-discipline and consultant inputs and cross references."

A geologist wrote: "Excellent introduction to surficial processes for a bedrock mapper. I really enjoyed the soils portions of the workshop."

"Congratulations! I felt that the study was one of the best interdisciplinary events that I've attended. Most everyone I talked with felt the same way. I'm sure the logistics of setting up a function of that magnitude was daunting at first, but it came off very well."

Finally, many asked for further workshops on this topic, as was best summarized by the comment: "Do this again!"

The real results of the field workshop go beyond the survey evaluations to the success of organizing and implementing this unique learning experience. The field day attracted a truly multi-disciplinary audience and presented a highly technical and cutting edge topic which has far-reaching environmental implications for Ohio.

## DISCUSSION

The survey response rate, 33 out of 175, or 19%, was disappointing. In retrospect, the survey administration and return process was not as well developed as it should have been.

While the evaluation results were somewhat variable, as might be expected for such an extremely diverse group with such wide-ranging interests, overall the whole workshop received a "good" rating. Especially with the more technical presentations in the field, the split between those who considered a given presentation to be excellent and those who considered it just average or below average was about equal, but the ratings patterns often reversed as individuals reached the technical presentation that most mirrored their own field of interest. Of the 15 evaluations submitted by geologists and/or hydrogeologists, all field sites were rated 3 or higher and unanimously rated the large pit as 5. The two surveys submitted by sanitarians gave lower ratings for geophysics (azimuthal resistivity and gamma logging), but again rated the large pit as 5. For the six soil scientists, the lowest ratings were given for core description, gamma logging, and drilling; as a group they gave the large pit a 4.33 average rating. The remaining nine unidentified responders rated all portions 3 and above. The highest overall rating given was for the large pit, with 82% of all survey respondents ranking that experience as being excellent. That site appeared to engender the most interaction among participants and attract the most attention. Even during breaks, individuals would remain in the pit to look at fractures and to talk with each other. Several individuals remained for at least an hour after the field day was ended to take more time to study the fractures that were identified in the pit sidewalls and bottom.

### Future Plans

Future field workshop educational offerings should include a pre- and post-test to measure the extent of participant learning. Likewise, a more organized method of collecting the participant evaluation surveys should be used to increase the response rate. Further research opportunities include holding fracture workshops for other audiences and comparing results across different groups of learners.

Because of the extensive amount of effort in planning, organizing, and running a field day at the scale of the August 1997 gathering, no additional field events were scheduled until May 2000. It is, however, obvious to those of us in the Working Group that we must continue to hold these events at colleges and universities around the state to continue the education process for the next generation of environmental professionals. Understanding why and how fractures form and identifying their environmental implications is a multidisciplinary effort. Those scientists who discovered the fractures are not those who understand why they form. Those scientists who understand their significance are not the planners and decision-makers who will have to evaluate the future land uses in light of our fractured landscape. Understanding occurs only when communication occurs. It is the mission of the Working Group and The Ohio Academy to promote that communication in an open and scientific forum.

The Ohio Fracture Flow Working Group is currently planning additional educational outreach efforts. Ten presentations were given at the 1998, 1999, and 2000 Annual Meetings of The Ohio Academy of Science. Two members of the team traveled to Copenhagen, Denmark in May 1998 to present two papers at the Mass Transport in Fractured Aquitards and Aquifers Conference.

This special issue of *The Ohio Journal of Science* has been published to document some of the research efforts here in Ohio and create a summary of efforts under way around the world. A web page dedicated to fracture research now exists (Fractures in Ohio's Pleistocene Unconsolidated Deposits and Soils, 2000). In its early stages, it served as a connector to all of the State and Federal websites which house information related to fracture flow. It also holds an extensive bibliography of references relating to fracture flow research. This bibliography will be updated on a regular basis.

The Ohio Fracture Flow Working Group is exploring the possibility of creating a permanent soils/glacial teaching and interpretation pit at the Gwynne Conservation (education) Area of the Molly Caren Agricultural Center. This pit would be open by appointment to school groups from elementary school to college levels and, at specific times, to the general public. The Working Group is hosting the Water Management Association of Ohio's spring 2000 conference, and it is hoped that the group will also be able to host an international conference on the topic of fracture flow some time early in the 21st century.

ACKNOWLEDGMENTS. Many thanks are due to those who sponsored and participated in this field workshop including Bennett & Williams Environmental Consultants Inc., Ohio Department of Natural Resources (Division of Geological Survey, Division of Soil & Water Conservation, and Division of Water), The Ohio State University (College of Food, Agricultural & Environmental Science; Department of Food, Agricultural & Biological Engineering; School of Natural Resources, Soil Science Program), US Department of Agriculture (Agricultural Research Service and Natural Resources Conservation Service), Bowser-Morner Inc., Indiana Geological Survey, CK McFarland and Sons Inc., the Association of Ohio Pedologists, and The Ohio Academy of Science.

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